UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

ACRSR-2174

January 4, 2006

The Honorable Nils J. Diaz
Chairman
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: VERMONT YANKEE EXTENDED POWER UPRATE

Dear Chairman Diaz:

During the 528th meeting of the Advisory Committee on Reactor Safeguards, December 7-9, 2005, we discussed the Vermont Yankee Extended Power Uprate (EPU) Application. As part of this review, our Subcommittee on Power Uprates held a meeting on November 15 -16, 2005 in Brattleboro, Vermont to receive input from the public, the applicant, and the staff. A second Subcommittee meeting was held in Rockville, Maryland on November 29 - 30, 2005. During our review, we had the benefit of discussions with the staff, the public, and Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. (Entergy), the licensee. We also had the benefit of the documents referenced.

CONCLUSIONS AND RECOMMENDATIONS

1. The Entergy application for the extended power uprate at the Vermont Yankee Nuclear Power Station (VY) should be approved.

2. The change in the licensing basis associated with the requested containment overpressure credit should be approved.

3. Load rejection and main steam isolation valve closure transient tests are not warranted. The planned transient testing program adequately addresses the performance of the modified systems.

4. The times available to perform critical operator actions remain adequate under EPU conditions.

5. The margin added to the safety limit minimum critical power ratio (SLMCPR) is an appropriate interim measure until General Electric (GE) obtains additional data to complete the validation of nuclear analysis methods.

6. The monitoring that will be performed during the ascension to uprate power provides adequate assurance that, if resonant vibrational modes are induced in the steam dryer, they will be identified prior to component failure.

7. An enhanced, focused engineering inspection was performed. An additional expanded inspection is not warranted.

8. The review standard for extended power uprates (RS-001) provides a structured process for the review of applications for extended power uprates. Its continued use and improvement are encouraged.

BACKGROUND

Vermont Yankee Nuclear Power Station (VY) is a boiling-water reactor of the BWR/4 design with a Mark-1 containment. Entergy has applied for an extended power uprate of approximately 20% from the current maximum authorized power level of 1593 MWt to 1912 MWt. The application is similar to other uprates that have been approved within the last five years at Duane Arnold, Dresden Units 2 and 3, Quad Cities Units 1 and 2, and Brunswick Units 1 and 2. In Constant Pressure Power Uprates (CPPU), except for steam and feedwater flow rates, plant operating conditions are essentially unchanged from the pre-EPU values. The extra power is generated largely by flattening the power distribution across the core, and the fuel design safety limits are met at the proposed extended power uprate conditions.

DISCUSSION

When a large-break design-basis loss-of-coolant accident (LOCA) and anticipated transient without scram (ATWS) were analyzed at VY at the proposed EPU level using current design basis assumptions and methodologies, the available net positive suction head (NPSH) was found to be insufficient to avoid cavitation of the low pressure coolant injection (LPCI) and core spray pumps. The need for increased NPSH occurs because at the higher power level the suppression pool heats up more in both of these scenarios than at the currently licensed power level. In the calculations performed to support VY's existing operating license, containment pressure was assumed to be atmospheric when computing the available NPSH.

In its application, Entergy requests changing its licensing basis methodology to grant credit for containment accident pressure in determining available NPSH for emergency core cooling pumps for these LOCA and ATWS scenarios. Using conservative methods and a containment leak rate consistent with its technical specifications, Entergy has determined a conservative lower bound for the time-dependent pressure in containment that would result from these scenarios under EPU conditions. The incremental pressure credits that are requested for these two scenarios are less than these computed pressures. For the LOCA scenario, the maximum containment pressure credit is 6 psi, and the total time for which some overpressure credit is required is 56 hours. For the ATWS scenario, the corresponding values are 2 psi and 1 hour.

The ACRS has historically opposed a general granting of containment overpressure credit. In determining whether such credit should be granted, one aspect to be considered is whether practical alternatives exist, such as the replacement of pumps with those with less restrictive NPSH requirements. If no practical alternatives are available, important considerations include (1) the length of time for which containment pressure credit is required and (2) the margin between the magnitude of the pressure increment that is being granted and the expected minimum containment pressure. Another consideration is the nature of the containment design and whether it provides a positive indication of integrity, prior to the event, as is the case in subatmospheric and inerted designs.

Because of the plant configuration, extent of modifications required, and worker dose that would be involved, we conclude that there are no practical design modifications that would preclude the need to consider the request for containment overpressure credit. VY has an inerted containment. There is, then, a low likelihood of significant pre-existing containment leakage. For the ATWS scenario, the magnitude of pressure required to show adequate NPSH is small compared to the accident pressure, and the time during which the overpressure credit is required is short. For the LOCA scenario, although the duration for which the containment overpressure credit is required is comparatively long, the overpressure credit requested is smaller than what is conservatively predicted to be available.

Under the EPU conditions at VY, the general design requirements regarding single failures in design-basis accidents do not prevent granting of the overpressure credit for the LOCA scenario of concern. The worst single failure that was identified by the licensee involves loss of one train of heat removal from the suppression pool. Conservative, bounding calculations show that the containment overpressures during this scenario are higher than needed to provide sufficient NPSH. Allowing no credit for containment overpressure is equivalent to assuming an additional failure that causes loss of the overpressure. Thus, for all scenarios involving only a single failure, sufficient NPSH is available to ensure that pump cavitation damage is avoided. To maintain defense-in-depth, however, it has been staff practice to require the assumption that containment overpressure is not available in assessing the potential for pump damage.

In evaluating Entergy's request for containment overpressure credit, the staff included in its decisionmaking process more realistic analyses to determine whether containment overpressure would be needed at the proposed EPU power level to prevent pump cavitation in actual accident scenarios. The staff also considered the results of probabilistic analyses to assess the risk significance of scenarios in which containment overpressure is lost.

Design-basis accidents are typically analyzed using conservative methodologies and input assumptions to ensure safety in spite of uncertainties in input and methodology. An alternative approach is to use realistic analyses with a more complete and explicit consideration of uncertainties. Such a methodology has not yet been fully developed for analysis of the need for containment overpressure credit. The staff and the licensee have instead performed sensitivity analyses to determine the effect of relaxing some of the conservative assumptions. More realistic values were used for a number of input parameters to determine the associated reduction in the predicted temperature of the suppression pool, which is the major parameter in determining whether overpressure credit is necessary. The staff concluded that, on a more realistic but still conservative basis, the temperature of the suppression pool would not become high enough in the LOCA scenario to require a credit for containment overpressure.

Independent risk analyses were performed by the staff and the licensee to determine the potential risk significance of granting credit for containment overpressure. These analyses included the conservative assumption that the emergency core cooling system (ECCS) success criteria would not be met whenever containment overpressure is lost and design-basis analyses would suggest that overpressure credit was needed, although the licensee's sensitivity studies indicated that peak suppression pool temperature would probably not be high enough that containment overpressure credit would be required. The results of the analyses indicate that the overall risk associated with the EPU is small and that the change in risk resulting from allowing the requested containment overpressure credit is also small.

Although we concur with the staff's conclusion to grant credit for containment overpressure, we would have preferred to see the assessment performed and presented in a more coherent manner, with a more complete and rigorous consideration of uncertainties. The staff is developing additional guidance to be used in the consideration of overpressure credit in the future. We look forward to reviewing their proposed approach.

The staff performed an expanded engineering inspection of VY. Such an inspection was requested by the Public Service Board of the State of Vermont. The inspection focused on safety-significant components and operator actions. It was performed under the direction of the NRC Office of Nuclear Reactor Regulation (NRR) and included regional inspectors and contractors who had no recent oversight responsibilities for VY. There were eight findings, but they were of low safety significance. A number of members of the public asked for a more extensive inspection, similar to that performed at the Maine Yankee plant. Based on the results of the inspection that was performed and the performance of VY as determined by the Reactor Oversight Process, such an extensive inspection is not warranted.

Hardware and operational changes are required for the power uprate. In order to achieve the proposed EPU power level, all three feedwater pumps must operate, rather than the two pumps currently required. If one of these pumps fails, the plant will undergo an automatic runback of power so that the two remaining pumps will be sufficient. A new signal has been added to trip a feedwater pump in the event of a condensate pump trip. A concern has been raised about the potential for loss of all feed pumps due to low suction pressure as a result of a condensate pump trip. Consequently, Entergy has agreed to perform a trip of a condensate pump to demonstrate that it will not cause loss of all feedwater. This will also test the integrated response of control systems associated with recirculation flow runback, feedwater level control, and reactor pressure control.

Entergy does not plan to undertake large transient tests, such as a main steam isolation valve closure that would result in a reactor trip. Such tests would not directly address confirmation of the performance of systems changed to support EPU. The ACRS concurs with the staff's assessment that the large transient tests are not warranted.

Only minor changes have been made in the emergency operating procedures to accommodate EPU modifications. One of the impacts of the power uprate is a reduction in available response time for operator actions. The operators respond in essentially the same manner as for the current operating conditions but, in some cases, have less time to take an action. A systematic assessment has been made by Entergy of the maximum time available for critical operator actions. The VY simulator has been modified to represent the EPU condition and operators have been trained for EPU conditions. The simulator exercises have demonstrated the ability of the operators to respond correctly within the required time period.

The reactor operating domain is defined so that: (1) the core will not be operated in an unstable regime, (2) the minimum critical power ratio is low enough to prevent dryout of the fuel pins, and (3) the linear heat generation rate is low enough to assure the integrity of fuel cladding during steady and transient conditions. The boundaries of this operating domain are based on neutronic and thermal-hydraulic calculations performed by GE. The computer codes that are used in these analyses have been reviewed and approved by the staff.

In reviewing the application of these methods to EPU uprates, the staff determined that the operation of the fuel extends into a region where the expected void fraction within the fuel bundle is greater than that for which the codes have been validated. To demonstrate the ability of the code to predict isotopic concentrations in this regime, GE has committed to performing gamma scans on the fuel design that is being used in the power uprate. In the interim, Entergy has undertaken an "Alternative Approach" in which it has performed an uncertainty analysis for the model predictions and, as a result, has added an additional margin of 0.02 to the SLMCPR. We concur with the staff's assessment that the addition of such a margin is an appropriate interim measure. The review of the adequacy of the GE computer codes is a generic activity that is being undertaken by the staff. We will have an opportunity to review the staff's assessment of these codes in more detail when we consider the MELLLA+ topical report in 2006.

Higher steam and feedwater flow rates at EPU conditions may lead to an increase in flow accelerated corrosion for some components. The evidence indicates that current flow accelerated corrosion rates at VY are low. Many of the components that would most likely be affected use chromium- molybdenum alloy materials that are resistant to flow accelerated corrosion, and Entergy has committed to an inspection program that will provide reasonable assurance that degradation will be detected prior to reaching an unsafe condition.

Increased flow rates also have the potential to induce vibrations that could lead to failure of components. Because of the previous experience at Quad Cities, the steam dryer has been the primary focus of attention. A number of cracks have been found in inspections of the VY steam dryer. Two cracks found near the lifting lugs were attributed to the initial fabrication of the steam dryer. These cracks have been ground out and repaired. The other cracks that have been found appear to be superficial and were deemed to be the result of intergranular stress corrosion, not flow-induced vibration. Stiffeners have been added to the dryer to provide additional strength and also to raise its natural frequencies.

Entergy has performed hydrodynamic, acoustic and structural resonance analyses to assess the potential for stimulation of a resonant mode of the dryer. These analyses indicate that there is margin between the magnitude of the potential stresses imposed on the steam dryer and the level at which fatigue failure would occur. However, the state of validation of these methods is poor.

To provide further assurance of the integrity of the dryer, additional strain gages have been added to the steam lines at VY. Experiments performed in a scale-model system by GE indicate that acoustic signals initiated in the region of the steam dryer can be correlated with signals measured by strain gages on the steam lines. A similar correlation has been observed at Quad Cities Unit 2 where both the steam dryer and steam lines have been instrumented.

Entergy has developed a program for power ascension involving holds at a number of power levels. The steam line strain gages will be monitored at the various power levels. Any anomalies will lead to a reduction in power until the issue is resolved. Entergy has also committed to inspections of the steam dryers in the next three outages following the uprate. The additional monitoring, the power ascension program, and the inspections provide confidence that, if excessive excitation does occur in the steam dryer, it will be identified before substantial damage is incurred.

Power uprates are not submitted as risk-informed license applications. Nevertheless, licensees have submitted assessments of risk associated with the extended power uprates and the staff includes consideration of this risk information in its decisionmaking process. The purpose of the staff's risk review as stated in RS-001 is to "determine if there are any issues that would potentially rebut the presumption of adequate protection provided by the licensee meeting the deterministic requirements and regulations." The staff has reviewed Entergy's assessment of risk at the proposed EPU conditions and compared the VY probabilistic risk assessment (PRA) results with the staff's SPAR model results for this plant. The values of core damage frequency (CDF) and large early release frequency (LERF) are low and provide substantial margin to values that raise questions of adequate levels of safety. As we noted previously, the staff also used risk insights in their independent determination of the acceptability of the potential for pump cavitation during long-term core cooling in LOCA and ATWS scenarios.

This was the second application by the staff of RS-001 in the review of an EPU proposed upgrade. RS-001 provides a structured approach to the review.

Sincerely,

/RA/

Graham B. Wallis
Chairman

Additional Comments by ACRS Members Richard S. Denning, Thomas S. Kress, Victor H. Ransom, and Graham B. Wallis

Considering all the evidence, including precedents set at other similar plants, we agreed with our colleagues to approve the proposed 20% EPU for VY.

It seems unlikely that there will be a problem with adequate NPSH of the core spray and residual heat removal (RHR) pumps at Vermont Yankee, with a 20% power uprate. However, we were asked to make a professional judgment that would have been more straightforward if the information supplied to us had been more complete. We suspect that more information already exists that could be reorganized, supplemented as needed, and presented logically to provide a more convincing case in the following way, which would set a better precedent for future applications:

1. Derive sufficient detail of the probability distribution for containment pressure following large LOCA and ATWS sequences, based on realistic analysis of the physical phenomena and the attendant uncertainties.

2. Derive sufficient detail of the probability distribution for suppression pool temperature following these events, based on realistic analysis of the physical phenomena and the attendant uncertainties.

3. Combine the results of steps 1 and 2 with realistic and uncertainty analyses of other phenomena influencing NPSH to derive the probability of successful operation of RHR and core spray pumps. This may provide adequate evidence for a conclusion to be reached, if it can be shown that only a small containment overpressure is likely to be needed for a short time, if at all, and it has a high probability of being available. If further evidence is required, these results can be incorporated into the PRA to derive the realistic contribution, if any, to total plant risk due to insufficient NPSH.

   Both Entergy and the staff have shown that relaxing a few of the many conservatisms and using realistic values (for example, of the initial temperature of the suppression pool) removes the need for additional NPSH. Such arguments are insufficiently conclusive. The reason is that when one gives up an element of conservatism, without replacing it by a less stringent assumption that is still demonstrably conservative, there is a finite probability that values of the derived parameter will not bound all possibilities. The proper way to relax the many conservative assumptions is to make (some of) them realistic with the inclusion of uncertainty. This will lead to a probability distribution (or more precisely some aspects of it, such as the 95/95 confidence level) for an output such as pool temperature.

   From the analyses that we have seen in presentations by Entergy and by the staff, it appears likely that the realistic contribution to risk from inadequate RHR and core spray pump NPSH will prove to be very small, even essentially zero, for the case of the proposed power uprate at VY, but this could be better demonstrated in a manner which is both physically and logically consistent. The probabilities associated with the governing physical phenomena may be regarded as more secure than some other inputs to the usual PRA assessment. Conclusions based on them may help to convince those who doubt if conventional risk-based arguments alone should allow the relaxation of defense-in-depth that is achieved by the independence of cladding and containment barriers to radioactivity release. In particular, if it can be shown that the probability of needing containment overpressure is sufficiently small, the independence of these barriers would effectively be preserved.

REFERENCES:

1. Memorandum from Ledyard B. Marsh to John Larkins, “Vermont Yankee Nuclear Power Station - Draft Safety Evaluation for the Proposed Extended Power Uprate (TAC No. MC0761)”, October 21, 2005

2. Letter from Wayne Lanning to Jay Thayer, “Vermont Yankee Nuclear Power Station, NRC Inspection Report 05000271/2004008", December 2, 2004

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* See previous concurrence.

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